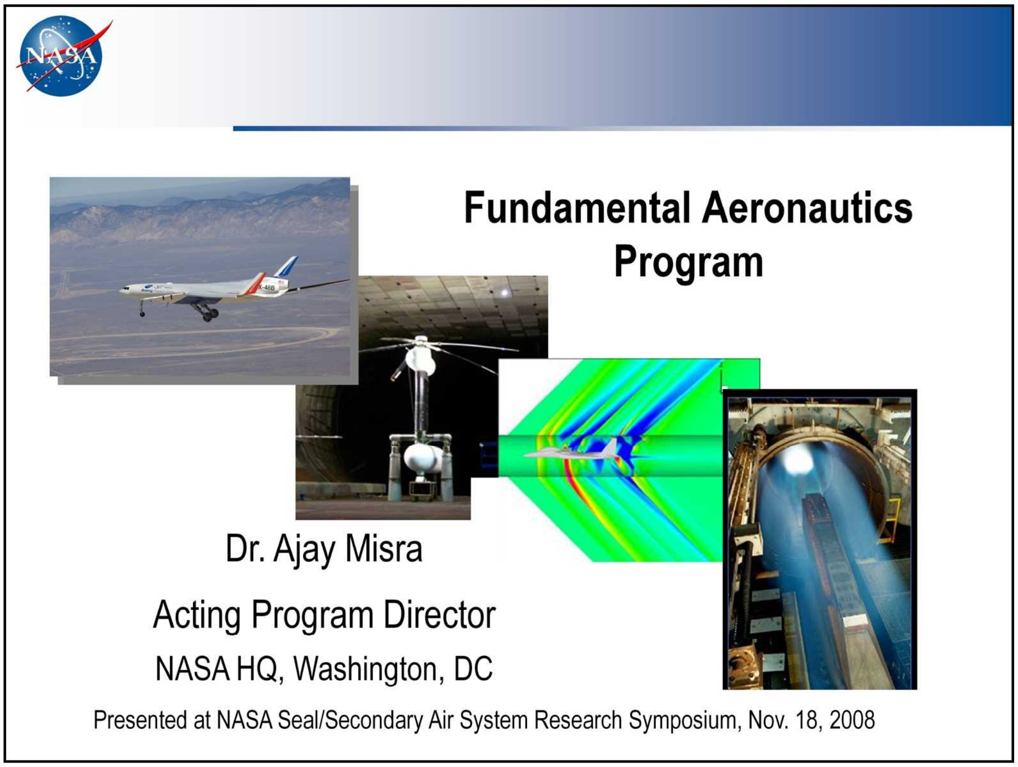
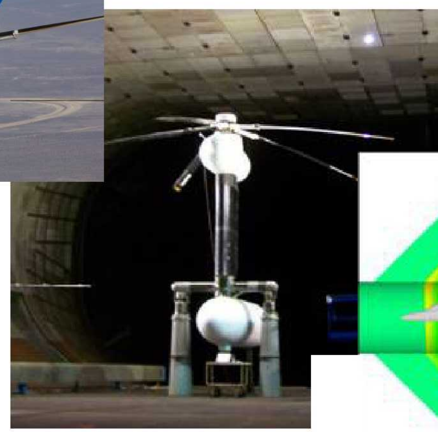
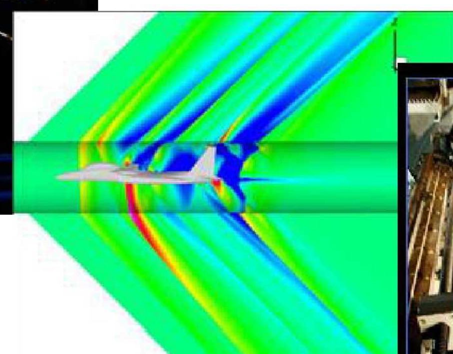
FUNDAMENTAL AERONAUTICS PROGRAM

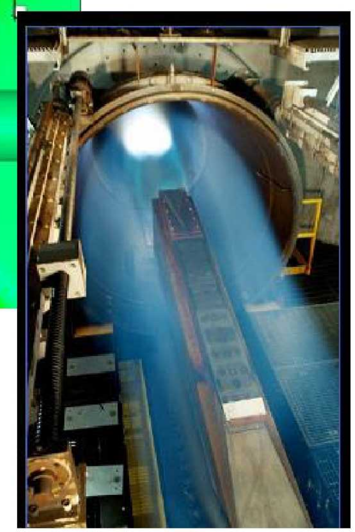
Ajay Misra
National Aeronautics and Space Administration
Headquarters
Washington, DC



Fundamental Aeronautics Program







Dr. Ajay Misra

Acting Program Director

NASA HQ, Washington, DC

Presented at NASA Seal/Secondary Air System Research Symposium, Nov. 18, 2008

ARMD Mission and Principles

The Overarching Mission of NASA's Aeronautics Research Mission Directorate (ARMD):

- To advance U.S. technological leadership in aeronautics in partnership with industry, academia, and other government agencies that conduct aeronautics-related research.
- ARMD supports the Agency's goal of developing a balanced overall program of science, exploration, and aeronautics, and ARMD's research plans also directly support the National Aeronautics R&D Policy and accompanying Executive Order 13419.

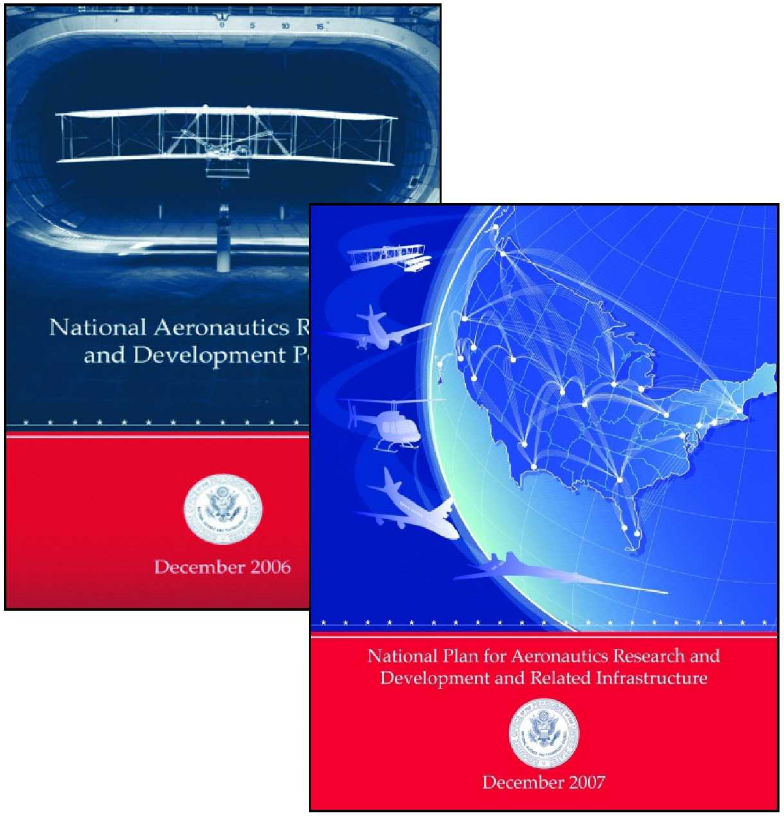
The Three Core Principles of ARMD:

- We will dedicate ourselves to the mastery and intellectual stewardship of the core competencies of Aeronautics for the Nation in all flight regimes.
- We will focus our research in areas that are appropriate to NASA's unique capabilities.
- We will directly address the fundamental research needs of the Next Generation Air Transportation System (NextGen) in partnership with the member agencies of the Joint Planning and Development Office (JPDO).

NASA/CP—2009-215677

ARMD Addresses National Aeronautics R&D Policy and Plan Objectives

- **Policy**
  - Executive Order signed December 2006
  - Outlines 7 basic principles to follow in order for the U.S. to “maintain its technological leadership across the aeronautics enterprise”
  - Mobility, national security, aviation safety, security, workforce, energy & efficiency, and environment
- **Plan (including Related Infrastructure)**
  - Plan signed by Pres. Bush December 2007
  - Goals and Objectives for all basic principles (except Workforce, being worked under a separate doc)
  - Summary of system-level challenges in each area and the facilities needed to support related R&D
  - Specific quantitative targets where appropriate



Executive Order, Policy, Plan, and Goals & Objectives all available on the web
For more information visit: http://www.ostp.gov/cs/nstc/documents_reports

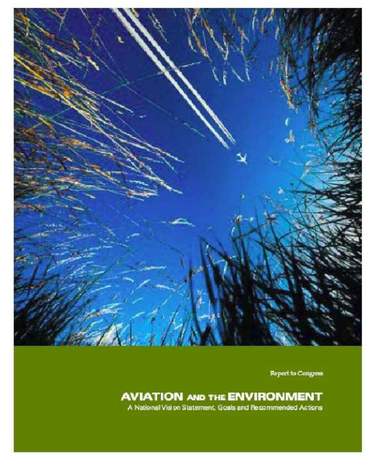
Research in Fundamental Aeronautics Will Enable Next Generation Air Transportation System (NextGen)

NextGen Vision for Environment:

Provide environmental protection that allows sustained aviation growth

Factors:

- 2X increase in system by 2025
- Fundamental system changes
- Increased importance of environment
- Vision to grow aviation while reducing *significant* environmental impacts



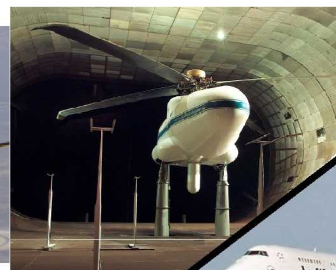
NASA Research Activities:

- Aggressive goals for reducing noise, emissions, and fuel burn for subsonic fixed wing, supersonic, and subsonic rotary wing vehicles
- Research the issues associated with deploying new or advanced air vehicles within NextGen

Aeronautics Programs

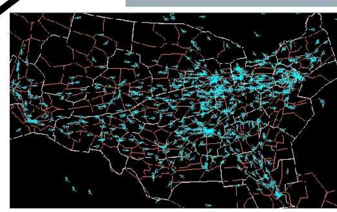
Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.



Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.



Airspace Systems Program

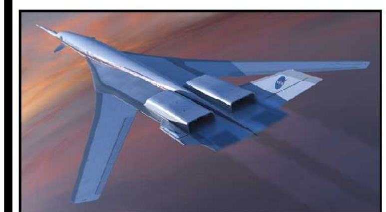
Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.

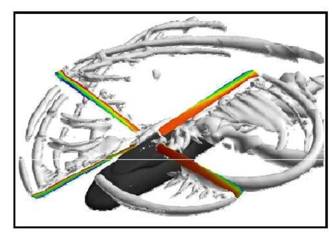
Fundamental Aeronautics Program Goals

- Conduct long-term cutting-edge research in all flight regimes to address main concerns of modern air transportation
  - Public concerns over ***noise and emissions***
  - Sustainability of affordable air travel with **increasing cost and availability of jet fuel**
  - Providing for ***mobility*** to meet increasing demand for air transportation
  - Lack of progress towards ***faster means of transportation***
- Enhance capability for future space exploration by addressing aeronautics-related challenges associated with
  - ***Airbreathing access to space***
  - ***Entry into a planetary atmosphere***

NASA Fundamental Aeronautics Program

- ***Hypersonics***
  - Conduct fundamental and multidisciplinary research to **enable airbreathing access to space** and **high mass entry into planetary atmospheres**
- ***Supersonics***
  - **Eliminate environmental and performance barriers** that prevent **practical supersonic vehicles** (cruise efficiency, noise and emissions, performance)
  - Develop supersonic deceleration technology for **Entry, Descent, and Landing** into Mars
- ***Subsonic Fixed Wing (SFW)***
  - Develop concepts/technologies for enabling dramatic improvements in ***noise, emissions and performance*** **(fuel burn and reduced field length)** characteristics of subsonic/transonic aircraft
- ***Subsonic Rotary Wing (SRW)***
  - Radically **Improve capabilities and civil benefits of rotary wing vehicles** (vs fixed wing) while maintaining their unique benefits





Common for all projects: Develop **prediction and analysis tools** for reduced uncertainty in design process and advanced **multidisciplinary design and analysis capability** to guide our research and technology investments and realize integrated technology advances in future aircraft

SFW System Level Metrics

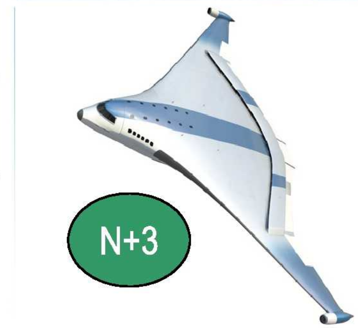
.... technology for dramatically improving noise, emissions, & performance

CORNERS OF THE TRADE SPACE	N+1 (2015 EIS) Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020 IOC) Generation Unconventional Hybrid Wing Body (relative to B777/GE90)	N+3 (2030-2035 EIS) Generation Advanced Aircraft Concepts (relative to user defined reference)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)	55 LDN (dB) at average airport boundary
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

** An additional reduction of 10 percent may be possible through improved operational capability

* Concepts that enable optimal use of runways at multiple airports within the metropolitan areas

--- EIS = Entry Into Service; IOC = Initial Operating Capability



Approach

- Enable Major Changes in Engine Cycle/Airframe Configurations

- Reduce Uncertainty in Multi-Disciplinary Design and Analysis Tools and Processes

- Develop/Test/ Analyze Advanced Multi-Discipline Based Concepts and Technologies

- Conduct Discipline-based Foundational Research

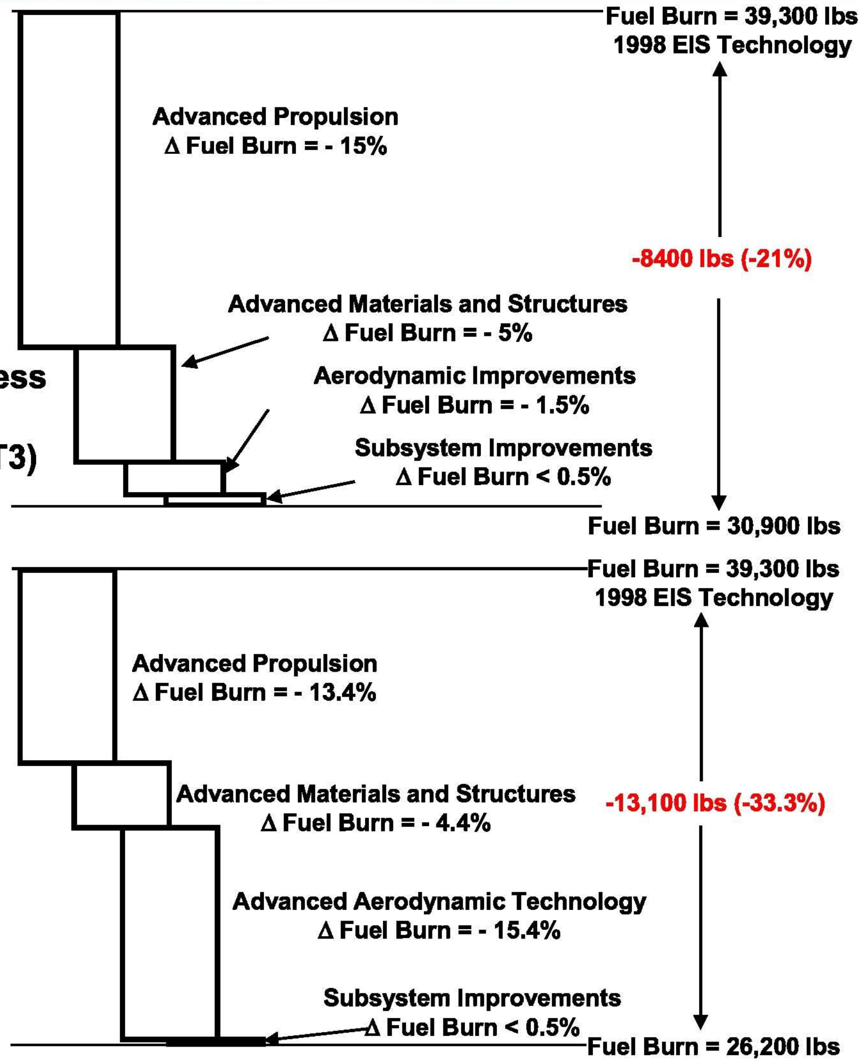
Performance - Fuel Burn - N+1
Detailed System Analysis

"N + 1" Conventional Small Twin

- 162 pax, 2940 nm mission baseline
- Ultra high bypass ratio engines, geared
- Key technology targets:
  - +1 point increase in turbomachinery efficiencies
  - 25% reduction in turbine cooling flow enabled by: improved cooling effectiveness and advanced materials
  - +50 deg. F compressor temperatures (T3)
  - +100 deg. F turbine rotor inlet temperatures
  - -15% airframe structure weight
  - -1% total vehicle drag
  - -15% hydraulic system weight

"N + 1" Advanced Small Twin

- All technologies listed above plus:
  - Hybrid Laminar Flow Control
    - 67% upper wing,
    - 50% lower wing,
    - tail, nacelle
  - Result = -17% total vehicle drag



Performance - Fuel Burn - N+2

Detailed System Analysis

Tube and Wing
Fuel Burn = 237,000 lbs
1997 EIS Technology

Hybrid Wing Body configuration
with composite fuselage
(Sandwich Construction)
Δ Fuel Burn = - 10%

300 pax, 7500 nm

Advanced Propulsion (Podded)
and Airframe Technologies
(composite wings)
Δ Fuel Burn = - 10%

-95,900 lbs (-40%)

Advanced Propulsion (Embedded)
and BLI inlets
Δ Fuel Burn = - 14%

Aerodynamic Improvements
(Hybrid Laminar Flow Control)
Δ Fuel Burn = - 6%

Fuel Burn = 147,595 lbs

Supersonics – System Level Goals and Metrics

	N+1 Supersonic Business Jet Aircraft (2015)	N+2 Small Supersonic Airliner (2020)	N+3 Efficient Multi-Mach Aircraft (2030-2035)
Cruise Speed	Mach 1.6-1.8	Mach 1.6-1.8	Mach 2.0 Unrestricted Flight 1.6-2.0 Low Boom
Range (nmi)	4,000	4,000	6,000
Payload	6-20 pax	35-70 pax	100-200 pax
Sonic Boom	65-70 PLdB	65-70 PLdB	65-70 PLdb low boom flight 75-80 PLdB unrestricted flight
Airport Noise (cum below Stage 3)	10 EPNdB	10-20 EPNdB	20-30 EPNdB
Cruise Emissions Cruise Nox EI	Equivalent to Subsonic	<10	<5
Other		?	?
Fuel Efficiency	Baseline	15% Improvement	25% Improvement

N+1 "Conventional"

N+2 Small Supersonic Airliner

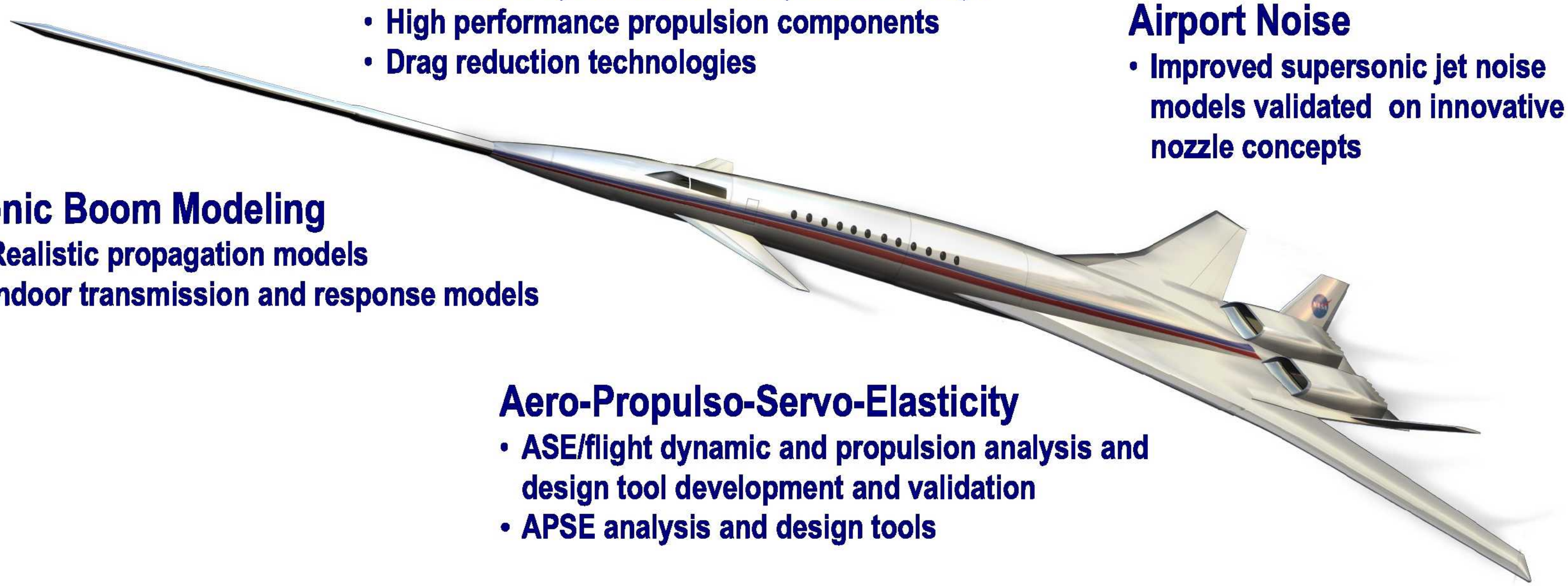
N+3 Efficient Multi-Mach Aircraft

Supersonics Project Technical Elements - Part 1

Deliver Knowledge, Capabilities, and Technologies Addressing Supersonics Challenges

Cruise Efficiency
- Tools and technologies for integrated propulsion and vehicle systems level analysis and design
- High performance propulsion components
- Drag reduction technologies

Airport Noise
- Improved supersonic jet noise models validated on innovative nozzle concepts



Sonic Boom Modeling
- Realistic propagation models
- Indoor transmission and response models

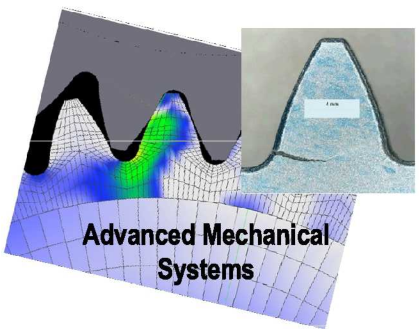
Aero-Propulso-Servo-Elasticity
- ASE/flight dynamic and propulsion analysis and design tool development and validation
- APSE analysis and design tools

High Altitude Emissions
- Improved prediction tools
- Low emissions combustors

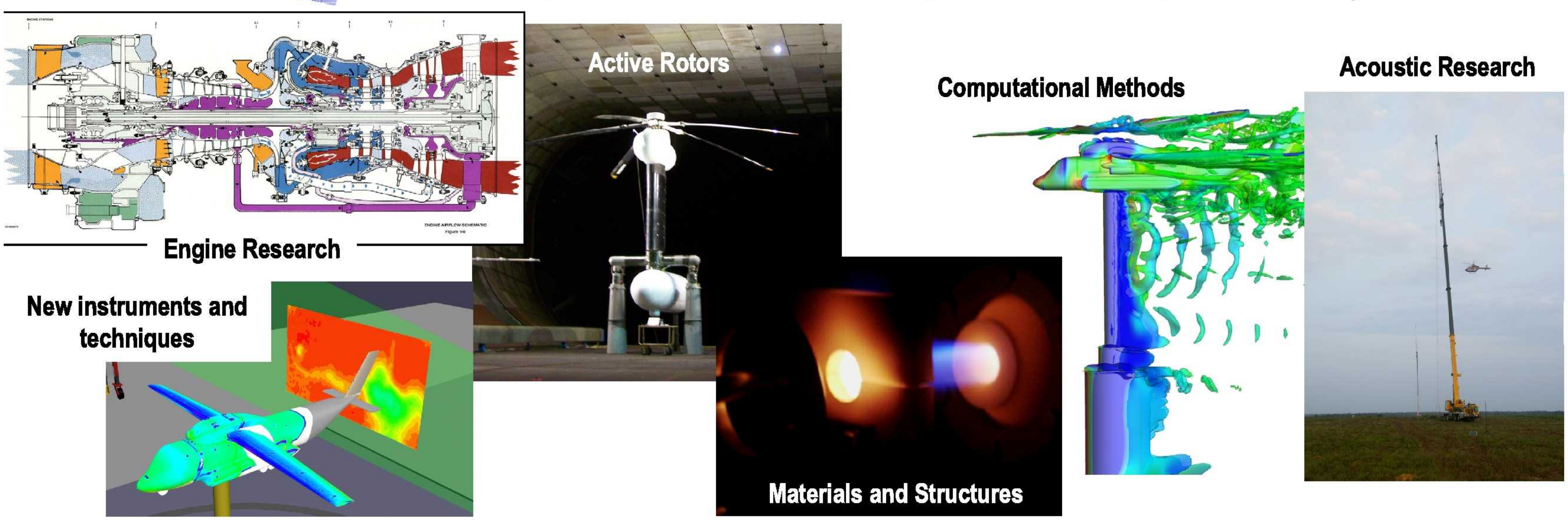
Light Weight and Durability at High Temperature
- Materials, test and analysis methods for airframe and engine efficiency, durability and damage tolerance

Subsonic Rotary Wing (SRW) Project

Goal: Radically Improve the capabilities and civil benefits of rotary wing vehicles



Civil Requirements (support NextGen)		Research Areas
Reduce airport congestion	→	Increase speed and range
Community acceptance	→	Noise propagation and reduction
Reduce emissions	→	Increase propulsion efficiency
Decrease cost, increase utility	→	Increase payload
Safe operations for advanced concepts	→	Improve control systems



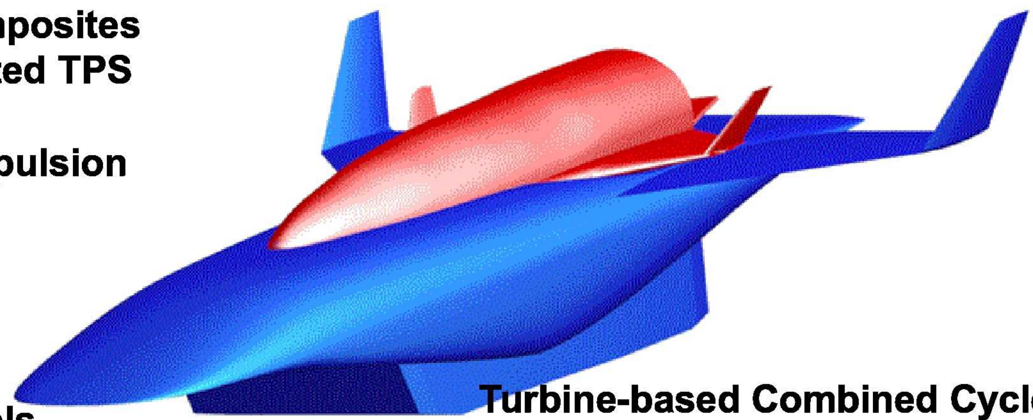
SRW High Level Goals

- Increase speed and range
  - Increase cruise speed of wide range of configurations by 100 knots
- Noise propagation and reduction
  - External noise contained within landing area
  - Internal noise reduced to 77dB
- Increase propulsion efficiency
  - 50% reduction in main rotor rpm
- Increase payload
  - 90 passengers, 10 tons
- Improve control systems
  - Achieve L1 Handling Qualities for advanced, high-speed concepts

Hypersonics-HRRLS Project Focus

Highly Reliable Reusable Launch Systems (HRRLS)
NASA Two Stage To Orbit (TSTO) Reference Vehicle

Ceramic Matrix Composites
Structurally-integrated TPS
Hot Structures
Actively-cooled propulsion
Integrated Controls



CFD Methods
Physics-based Models
Physics-based MDAO
Vehicle Studies

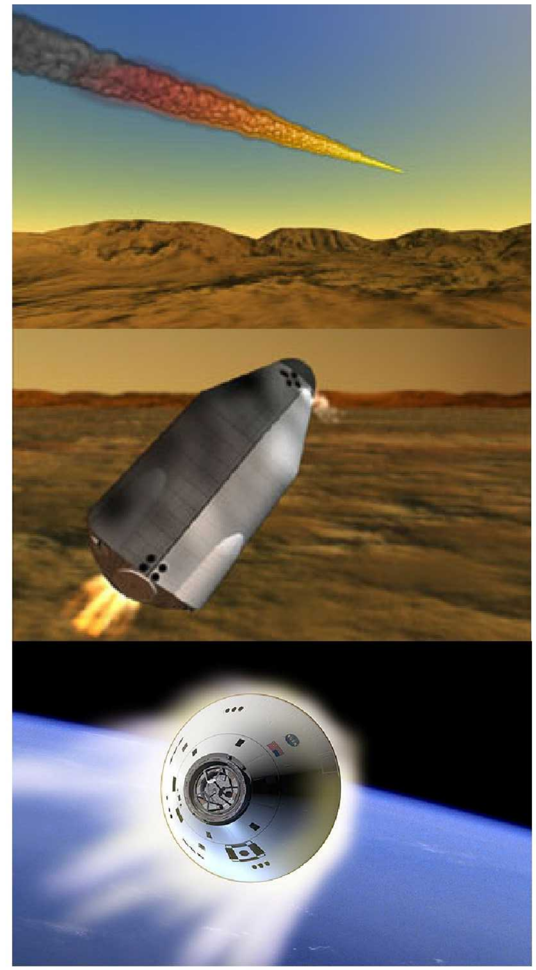
Turbine-based Combined Cycle Propulsion
Rocket-based Combined Cycle Propulsion
Combustion Physics
Non-Intrusive Diagnostic Tools

Addressing challenges in:
- Large uncertainty in prediction of aerothermal environment
- Integration, operability, and control of multi flow-path propulsion system
- Lightweight high temperature materials and structures
- High-fidelity multidisciplinary design analysis and optimization tools

Hypersonics HRRLS Goals

- Decrease uncertainty in aeroheating prediction by 50%
- Develop multi-use 3000°F structurally-integrated Thermal Protection Systems
- Develop air-breathing propulsion technology for Two-Stage-to-Orbit Vehicles
- Develop physics-based integrated multi-disciplinary design tools

High-Mass Mars Entry Systems (HMMES)



Challenge

Current technologies for atmospheric entry fall short of what is needed for landing high masses (> 1 MT) on Mars. Current studies indicate landed-mass capabilities must increase by two orders of magnitude to permit human-scale Mars landings.

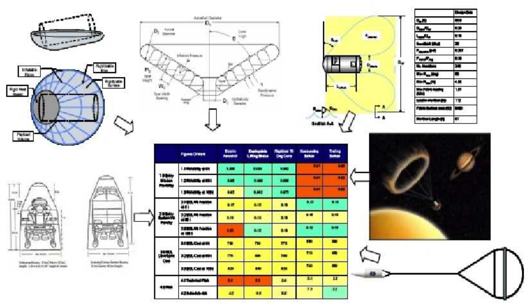
Goal

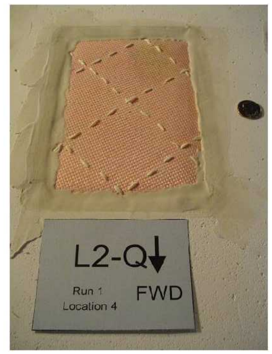
Develop new Entry, Descent, and Landing (EDL) technologies, along with the tools to design and analyze them, which enable High-Mass Mars Entry Systems.

Projects

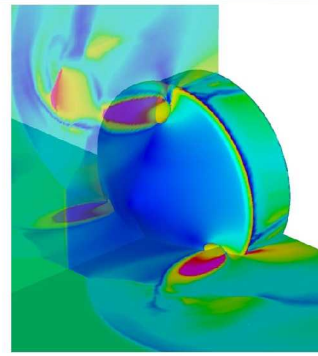
Hypersonics, Supersonics

Aeronautics Challenges for High-Mass Mars Entry Systems (HMMES)





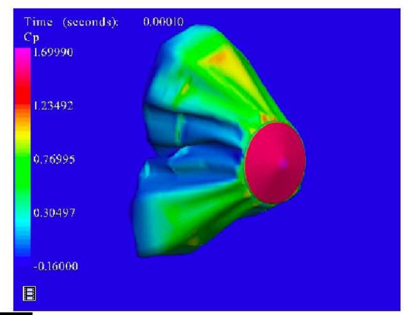
Flexible TPS



Fluid Dynamics
- Highly unsteady flow
- Turbulence
- Performance

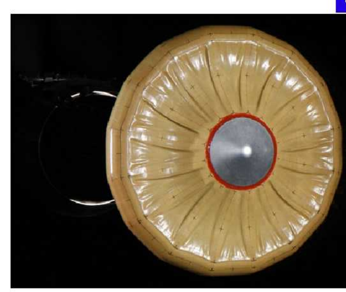
Vehicle System
- Physics-based models
- Physics-based MDAO
- Innovative concepts

Fluid-Structures Interaction
- Simulation tools for design
- Flexible membrane structures
- High-speed deployment



Propulsive Deceleration
- Analytical tools and methods
- Reaction control systems

Advanced Ablators
- New materials
- High fidelity ablation models



Inflatable Decelerator

Cementing Partnerships...

NEXT GENERATION AIR TRANSPORTATION SYSTEM
JOINT PLANNING & DEVELOPMENT OFFICE

U.S. ARMY

U.S. AIR FORCE

National Nuclear Security Administration
U.S. Department of Energy

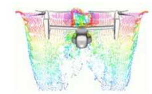
BRIDGING THE GAP
1958 DARPA 2008
50 YEARS
POWERED BY IDEAS

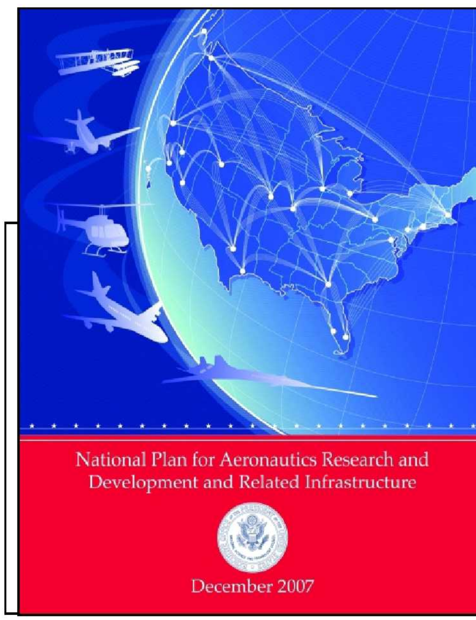
NASA ARMD Participation in the CLEEN Program

CLEEN Program Market Survey Conference
Washington, DC
May 15, 2008

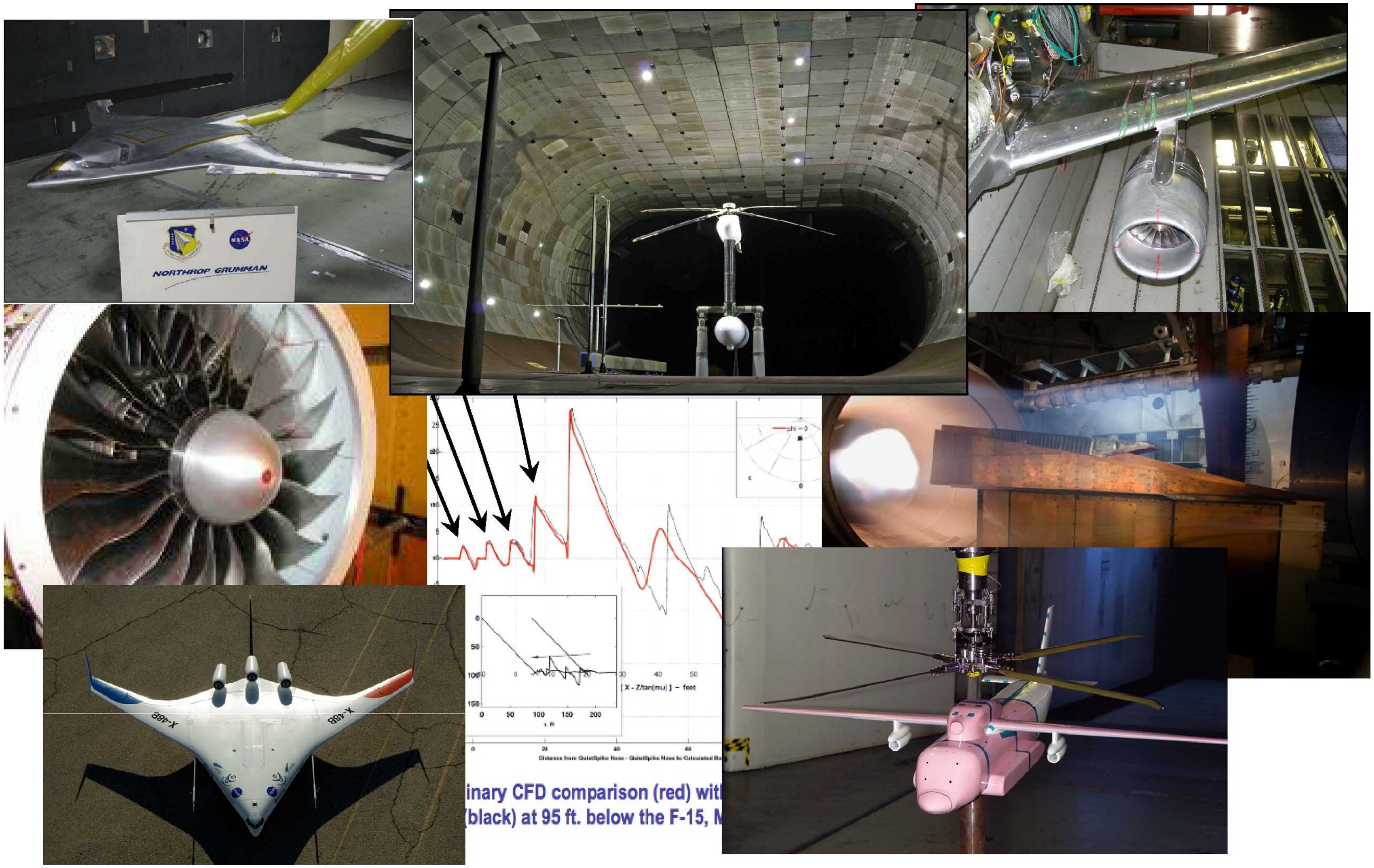
Juan J. Alonso
Director, NASA Fundamental Aeronautics Program





…Delivering Results



Technical Accomplishments - FAP

- Completed 30 X-48B flights to demonstrate low speed flying, handling capabilities, and flight under stall conditions
  - Partnership with Boeing and AFRL

- Completed integration and interference test of high by-pass geared turbofan engine in ARC 11-ft tunnel to address integration of high bypass engine with the aircraft
  - Partnership with Pratt and Whitney

- Completed smart rotor testing in NFAC to demonstrate effectiveness of flap for noise and vibration control and to validate acoustic prediction code
  - Partnership with DARPA and Army

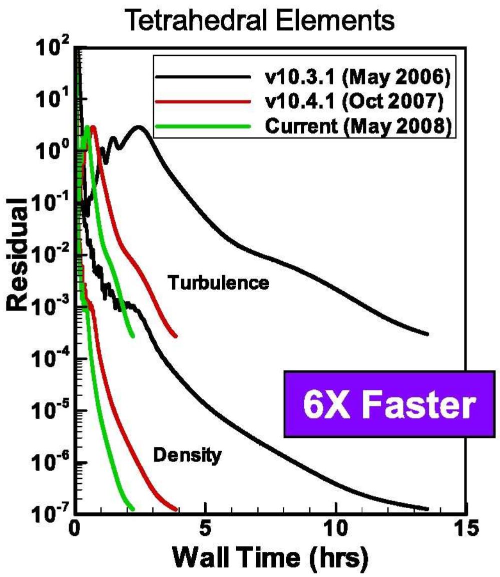
- SJX61-2 engine flight qualified for X-51A test vehicle through testing in high temperature wind tunnel
  - Partnership with Boeing, Pratt and Whitney, and AFRL

- Completed flight validation of non-coalescing shocklets produced from Quiet Spike configuration
  - Partnership with Gulfstream

Improving Time-to-Solution for Unstructured Grids

L-I

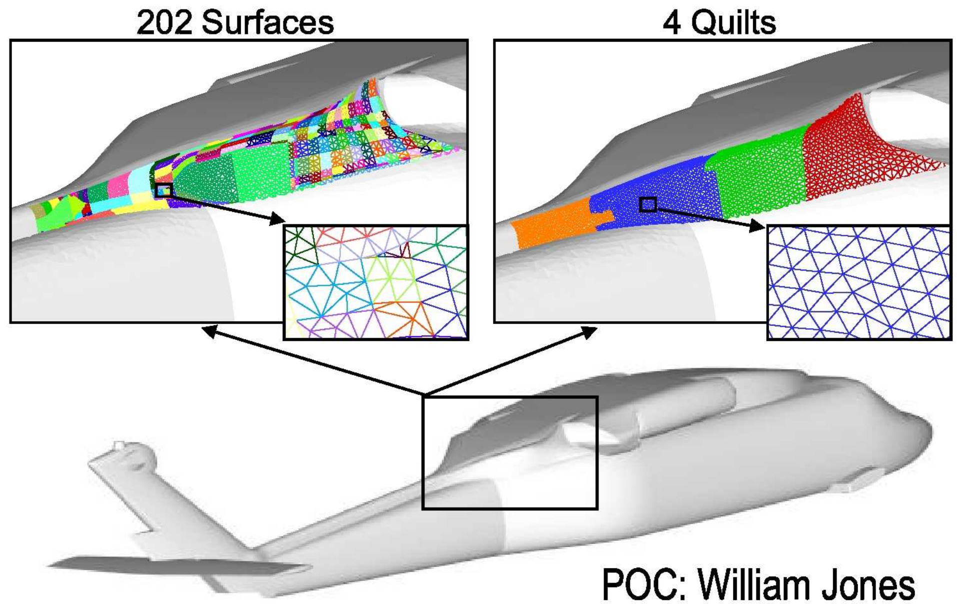
Improve FUN3D Efficiency



- 5.6M node Drag Prediction Workshop Wing/Body
- 64 Processors
- 3.6 Ghz P4 2GB w/GigE

POC: Eric Nielsen

"Quilting" for Grid Generation



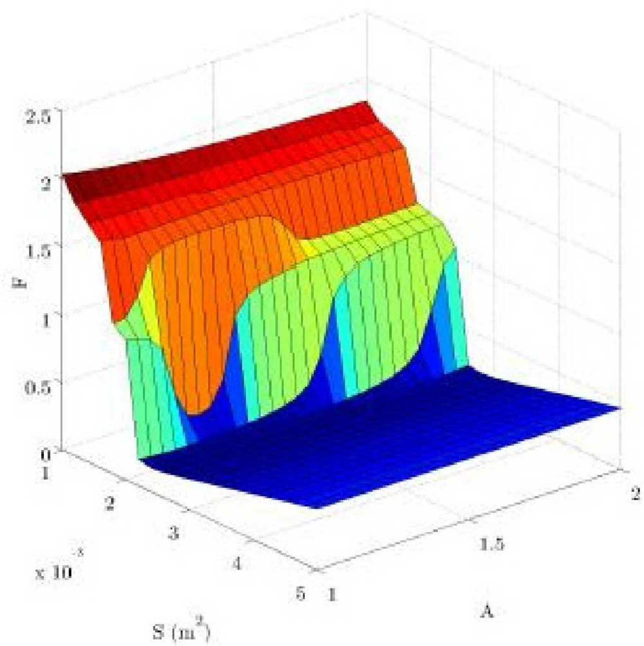
POC: William Jones

- **Higher-Order Time (4th) for Moving Grids**
- **Overset Mesh-Movement Masking**
- **$1/N_{BLADE}$ per Revolution Loose Coupling**

FUN3D collaborative software development framework: new capabilities continuously and seamlessly inherited by all code users

Multidisciplinary Analysis and Optimization is a Key Element of All Projects

"Develop fast and effective physics based multi-disciplinary analysis and design tools with quantified levels of uncertainty that enable virtual expeditions through the design space."

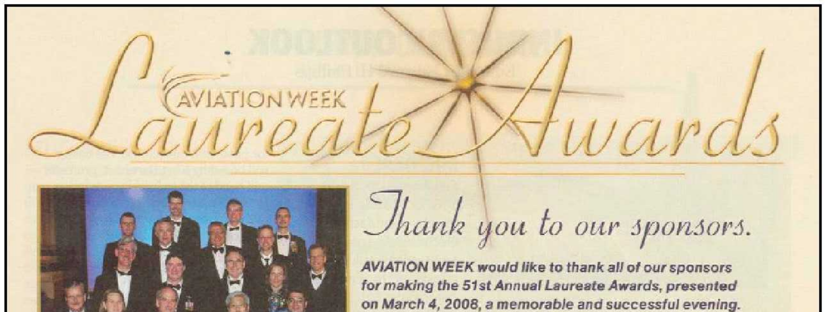


Virtual Expeditions through Design Space

- Enable unconventional vehicle synthesis and analysis through a shift from *empirically based, non-integrated, low fidelity deterministic methods* to more *physics based, integrated, variable fidelity probabilistic methods*.
- Enable the critical sizing and early configuration trade studies of both conventional and unconventional designs.

Being Recognized for What We Do

Quiet Spike: Gulfstream, NASA



AVIATION WEEK Laureate Awards

Thank you to our sponsors.

AVIATION WEEK would like to thank all of our sponsors for making the 51st Annual Laureate Awards, presented on March 4, 2008, a memorable and successful evening.

AERONAUTICS/PROPULSION

The Quiet Spike Flight Test NASA/ Gulfstream Team Robert Cowart, Project Engineer, Gulfstream Aerospace; **Donald Howe**, Staff Scientist, Technical Fellow, Gulfstream Aerospace; **Leslie Molzahn,** Flight Test Operations Engineer, NASA Dryden Research Center; **Frank Simmons III,** PhD, P.E., Gulfstream Aerospace; and **James Smolka,** Research Test Pilot, NASA Dryden Research Center

BUSINESS/GENERAL AVIATION

Jack Pelton, Chairman, CEO and President, Cessna Aircraft Company

COMMERCI

John Byerly, U.S.

Transportation Affai

Transport Directorat

INFORMATI

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Capt. Karen D. Le

Airlines; **Capt. Rob**

Manager, UPS Airlin

Manager, Safe Fligh

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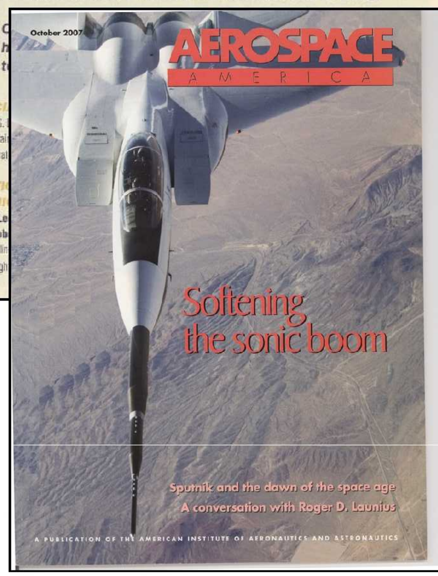
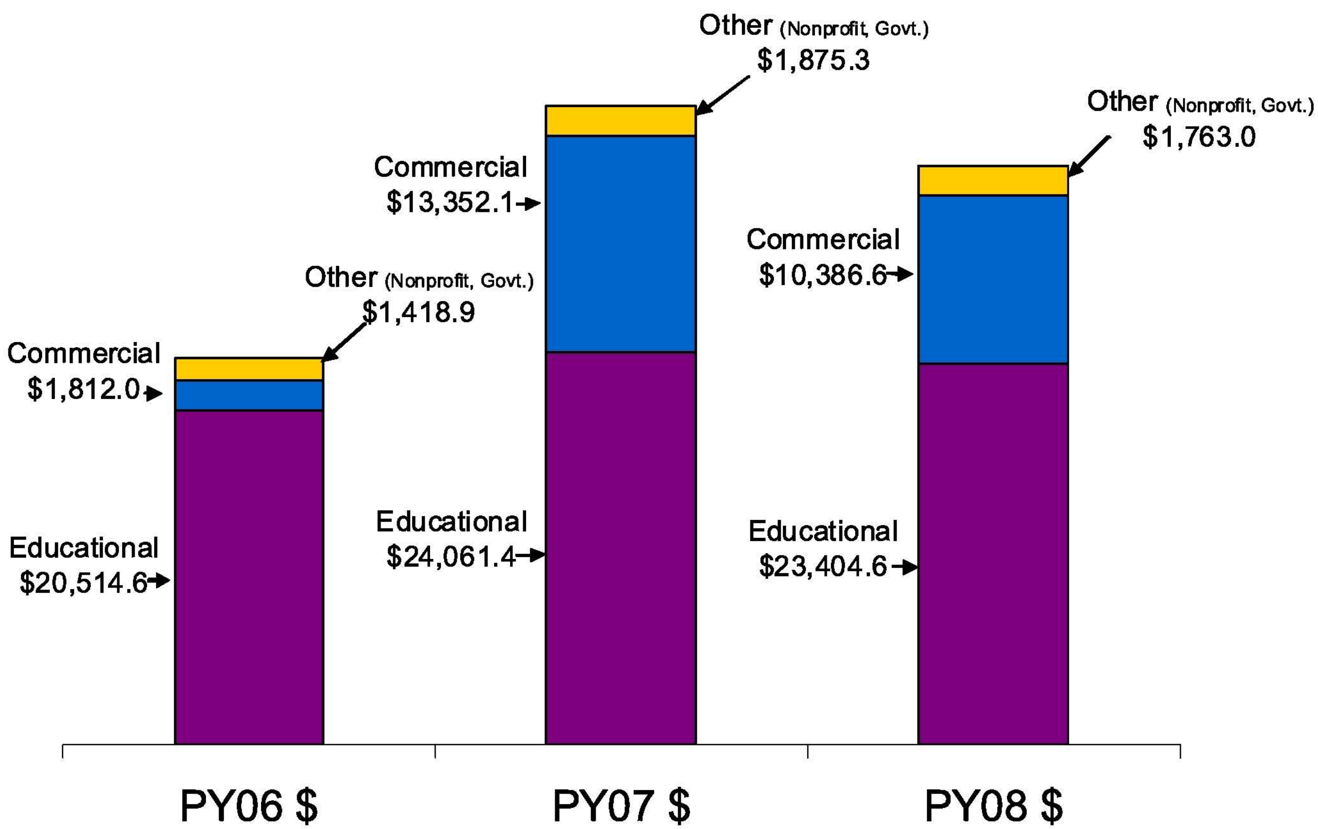


X48B: Boeing, NASA, AFRL

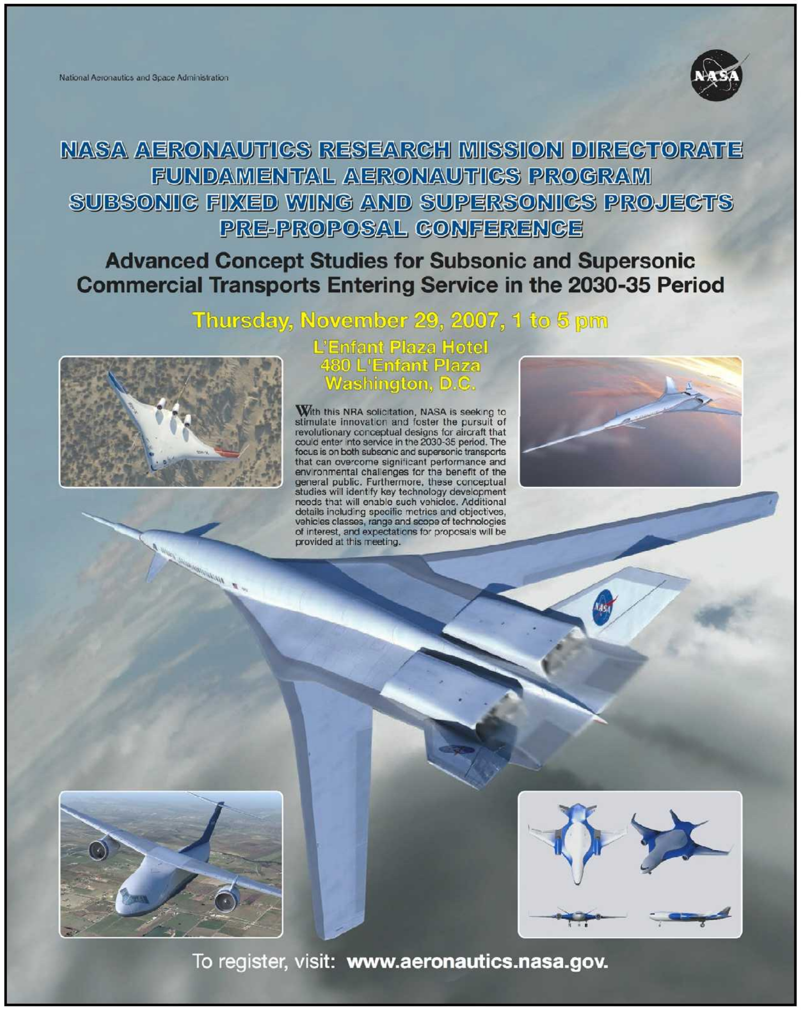
Time Magazine:
Best Innovations of the Year, 2007

Fundamental Aeronautics Program

Fundamental Aeronautics NRA Funding Trends



NASA NRA Pre-Proposal Conference, Nov 29



- ***Advanced Concept Studies for Subsonic and Supersonic Commercial Transports Entering Service in the 2030-35 Period***
- November 29, 2007, 1-5 pm
- L'Enfant Plaza Hotel, Washington, DC
- Stimulate innovation and foster the pursuit of revolutionary conceptual designs for aircraft that could enter service in the 2030-35 time period. Overcome significant performance and environmental challenges for the benefit o the public.
- Phase I: 12-Months, Phase II: 18 Months to Two Years, with significant technology demonstration

NASA N+3 NRA Selections

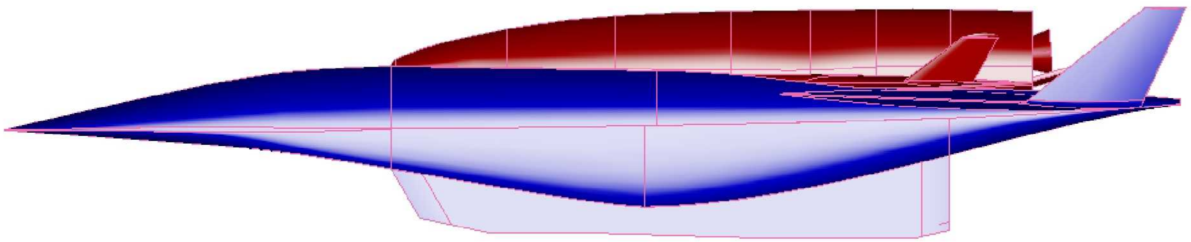
- Six teams have been selected and awards are in place. Four subsonic teams and 2 supersonic teams:
  - Subsonic Ultra-Green Aircraft Research (SUGAR), Boeing
  - Advanced Concept Studies for Subsonic Commercial Transport Aircraft Entering Service in the 2030-35 Time Period, Northrop Grumman
  - Aircraft & Technology Concepts for an N+3 Subsonic Transport, MIT
  - Small Commercial Efficient & Quiet Air Transportation for 2030-35, GE Aviation
  - NASA N+3 Supersonics - Three Generations Forward in Aviation Technology, Lockheed Martin
  - Advanced Concept Studies for Supersonic Commercial Transport Aircraft Entering Service in the 2030 -35 Time Period, Boeing

- Phase I: 18-Months, Phase II: 18 Months to Two Years, with significant technology demonstration

- Pursuing significant improvements to address some of the challenges of NextGen

National Hypersonic Science Centers

✓ Laminar-Turbulent Transition
(Boundary Layer Control)



✓ Materials & Structures

✓ Air-breathing Propulsion

Joint Effort with AFOSR

3 Centers

5 Years maximum with annual renewal

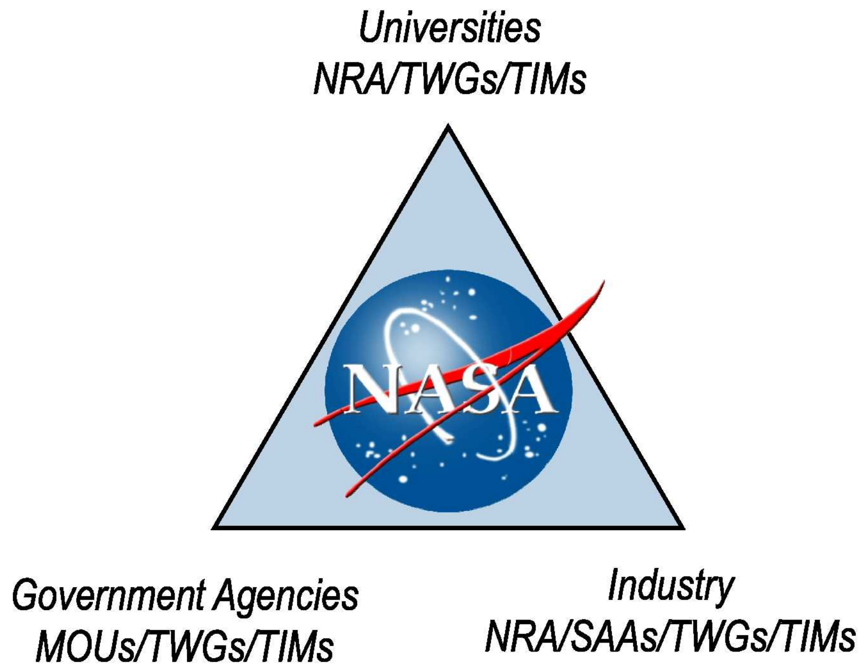
$30M maximum for all Centers combined

White Papers Due October 17, 2008

Final proposals due December 12, 2008

Partnering Philosophy

- Enhance the state of Aeronautics for the Nation
- Help foster a collaborative research environment in which ideas and knowledge are exchanged across all communities
- Maximize the return on investment to the taxpayer (our main stakeholder)
- Every element of our portfolio targets innovative, pre-competitive research that will advance our Nation’s aeronautical expertise
- In accordance with NASA’s Space Act (as amended) and the National Aeronautics R&D Policy, we will provide for the widest practical and appropriate dissemination of our research results (consistent with national security and foreign policy)



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Overview of the entire NASA Aeronautics Program

- Fundamental Aeronautics Program
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Overview of the entire NASA Fundamental Aeronautics Program

- Subsonic Fixed Wing Project
- Subsonic Rotary Wing Project
- Supersonics Project
- Hypersonics Project